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ABSTRACT

This paper presents the rationale, structure, and specifications for a model program for the preparation of chemists, chemical engineers, and high school chemistry teachers. The model (an application of systems technology to program development in higher education) is based on the structure provided by the Georgia Educational Model Specifications for the Preparation of Elementary Teachers. The proposed instructional program is based on performance specifications related to the three chemistry-related occupations and is arranged in a three-phase career sequence (preprofessional, professional, and specialist). Emphasis is on (1) individualization of instruction through the use of proficiency modules (student contract units classified by type and blocks and arranged in appropriate sequence); (2) increased on-the-job laboratory experience in five types of laboratory facilities; and (3) the process of continuous and differentiated evaluation. Illustrative materials include: a conceptual model of job analysis, essential parts of a complete proficiency module (PM), essential parts of each PM learning task, specifications for various study sequences, and a conceptual summary network for development and evaluation of the model. (ES)

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AN EXEMPLARY PROGRAM IN HIGHER EDUCATION FOR CHEMISTS, ENGINEERS AND CHEMISTRY TEACHERS

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INTRODUCTION

In 1967 concern for the improvement of programs in higher education led the United States Office of Education, Bureau of Research of the Department of Health, Education and Welfare to promote and support nine separate investigations designed to provide specifications for models of comprehensive and exemplary programs for the preparation of elementary teachers. Each of these projects was required to apply systems technology procedures. This became the first intensive application of research and development procedures characteristic of industrial, space and military operations to program development in higher education. The final reports of these investigations were published in the fall of 1968. Although each of these products has unique features there are many common characteristics.[1]

A careful study of these final reports revealed a basic program structure with outstanding characteristics that could be used for the creation of exemplary programs beyond the particular concerns of the investigations.

PURPOSE

The purpose of this paper is to project an exemplary program for the preparation of chemists, chemical engineers and high school chemistry teachers based primarily on the model or basic structure provided by the University of Georgia investigation.[2]

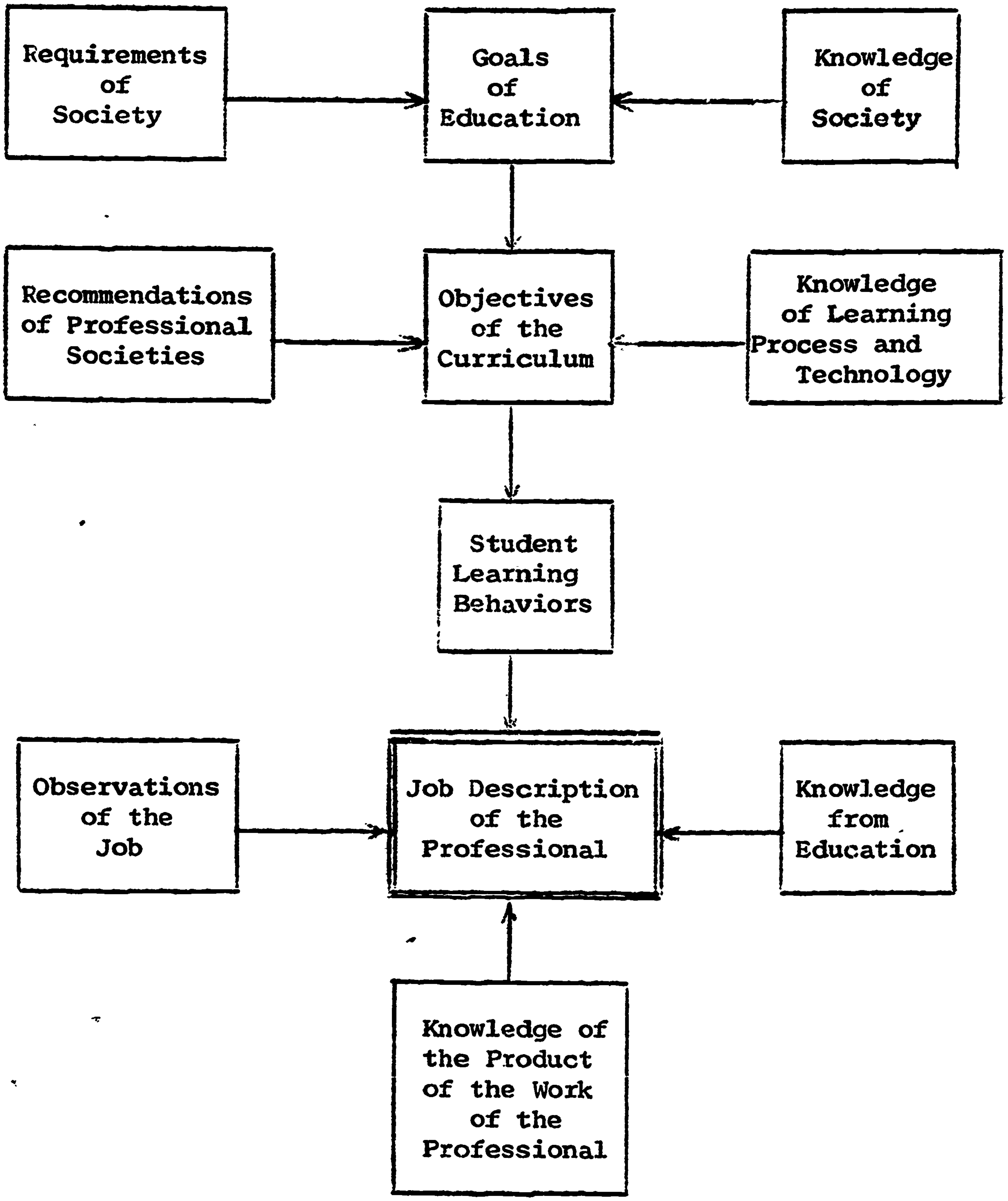
BEHAVIORAL SPECIFICATIONS

At the core of the exemplary program would be a comprehensive classified list of thousands of detailed behaviors required for acceptance in the professions. This list, drawn from job descriptions, would provide the specifications for the products of the program--the students to be graduated, certified or licensed. The nature of these specific statements of behavior would dictate the nature of the instructional program including the kinds of content required, teaching procedures, program sequence, materials for instruction and the system for evaluation.

The job descriptions from which these numerous characteristics were drawn would be the result of an intensive search for knowledge and information. Figure 1 illustrates the sources that would be used in the analysis to lead to these job descriptions. The requirements of society and knowledge from various resources and materials would have contributed to the determination of the goals of the program. These goals in turn would serve as bases for determining the objectives. The selection of the objectives would have been affected by the recommendations of such professional societies as the American Chemical Society, the American Society of

Figure 1

Conceptual Model of Job Analysis



Engineering Education and others and what was known of the effectiveness of educational technology. In addition, observations of workers on the job, knowledge of pedagogy, and information regarding the kinds of products to be supplied by the workers would be considered.

CAREER SEQUENCE

A special feature of the instructional program will be a career sequence. That is to say, as the student passes through the program he will move from level to level in the direction of the highest level of performance in the profession. Most professionals are responsible for all the tasks in the job description except those of the specialist. However, experience with aides, technicians and interns has shown that differentiated use of staff is feasible in using time and talent more effectively.

To assist the reader in understanding the career sequence feature of the program and the job analysis procedure the authors have prepared summary illustrations of projected job descriptions.

High School Chemistry Teacher

The career sequence of the high school chemistry teacher will be in four levels: aide, teaching assistant, teacher and specialist. A complete job description for each of these categories will be available.

The aide will perform a variety of important non-instructional tasks and activities under the direction of an experienced teacher. A person at this level is primarily concerned with gaining experience in the school setting. The academic preparation for this level will be high school graduation supplemented by some college training.

The teaching assistant will perform both instructional and non-instructional duties, thus assuming a more complex role than that of the aide. The assistant will generally be directed by the teacher with responsibility for initiating and executing a variety of tasks. The academic preparation will be equivalent to about two years of college.

The professional high school chemistry teacher will have completed the requirements for a bachelor's degree and for certification. The tasks performed at this level will be largely instructional. The professional program will provide the student with a special area of competency within chemistry and in most cases, the prerequisites for admission to the specialist program.

The specialist represents the highest level of competence provided in the program and performs in his field of specialty not only working with students but also by providing leadership and service to other school personnel. This perwil will, in most cases, be equalified to move into teaching at the junior college level.

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Chemist and Chemical Engineer

The job career sequence of chemists and chemical engineers will be a four level job description with four categories: aide, technician, chemist and/or engineer (professional) and specialist. A complete job description for each of these categories will be available.

The aide will perform a variety of non-technical tasks and activities under direction of an experienced professional. A person at this level is primarily concerned with gaining experience. Academic preparation for this level should be high school graduation supplemented by some college.

The second level of personnel is the technician. The technician will perform a variety of sub-professional and routine tasks, thus assuming a more complex role than that of the aide. The technician will generally be directed by the professional with responsibility for initiating and executing a variety of tasks. Academic preparation will be equivalent to about two years of college and eligible for certification as a technician.

The professional chemist or chemical engineer will have completed the requirements for a bachelor's degree and will be eligible for certification as a practicing chemist or chemical engineer. The tasks performed at this level will be of a professional nature. The professional program will provide the student with a special area of competency within chemistry or chemical engineering and, in most cases, the prerequisites for admission to the specialist program.

The specialist represents the highest level of competence provided by the program in the field of the student's specialty. The specialist will be responsible for highly specialized work, leadership, and service to other personnel. This person will, in most cases, be qualified to work toward the doctorate in his chosen field of specialization.

INDIVIDUALIZED INSTRUCTION

This program will require that all learning activities be individualized, as distinguished from individual or tutorial. Individualized instruction is based on the principle that all individuals differ from others in numerous characteristics related to learning, and that for effective learning these differences must be recognized and accounted for in all aspects of instruction. Provision for individualized instruction combined with the principle which requires that performance behaviors rather than letter grades or time serve as the criteria for success makes it possible for an exceptionally talented and well experienced student to complete any phase of the program in half the time or less of that required for an average student. On the other hand, it may be necessary for some students to exceed the time expectations of an average student.

To accomplish individualization the proficiency module (PM) has been developed as the vehicle for organization and presentation of learning activities and materials of instruction. The total program will be represented by hundreds of these PMs which might be regarded by some as individual guides to study. Figure 2 lists the essential parts of a complete PM. Figure 3 shows the essential parts of each of numerous learning tasks contained in the PMs.

The content for any PM will be a selected cluster of related performance behaviors including definitions, facts, and concepts as well as thought processes, motor skills, and attitudes. The core of the PM will be a series of learning tasks regarded as the most effective means of guiding students toward the acquisition of the performance behaviors. These tasks will provide multiple sequences for the attainment of the desired end making them adaptable to individual differences among students in such characteristics as rate of learning, sensory sensitivity and cognitive styles.

PROGRAM SEQUENCE

PMs will be classified by type and blocks. The term type refers to classes of PMs which group themselves around common functional relationships such as the basic PMs required for all students in the pre-professional program, and PMs required of all students enrolled for a particular competency.

Figure 2

Essential Parts of a Complete Proficiency Module

Classification	Tells block, subject area group, and topic.
Directions	Tells student how to proceed with PM.
Objectives and Behaviors	Tells the specific characteristics to be acquired--knowledges, processes, skills, attitudes.
Prerequisites	Lists the essential learnings required by the student to begin PM.
*PM Pretest	Presents diagnostic evaluation of initial status in relation to behaviors.
Learning Tasks	A sequence of learning activities.
*PM Posttest	Presents diagnostic evaluation of final status in relation to behaviors.

*Not contained in student's edition of PM.

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Figure 3

Essential Parts of Each
PM Learning Task

Purpose	Tells student what knowledges, processes, skills, and/or attitudes he is to learn through the activities of the task.
Resources	Lists outside resources which the student will need such as books, films, TV tapes, audio tapes, CAI programs, science equipment, microfilms, classrooms, clincs, and tells where they are found.
Procedures	Detailed instructions as to what learning behaviors the student is to perform in undertaking the learning task.
Evaluation	A self-administered evaluation device designed to indicate to the student the extent of his success.

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The term blocks refers to clusters of PMs, all of which must be taken before moving on to the next block. For example, there will be six PM blocks in the pre-professional high school chemistry teacher program and ten PM blocks in the professional program of chemists and chemical engineers. The student must meet the level of proficiency required by all of the PMs in any particular block in the sequence before he may move on to the next one.

Figures 4 and 5 show diagrams of the specifications of study sequence for the pre-professional and the professional phases in the training of high school chemistry teachers. Figures 6 and 7 present diagrams for the specifications of study sequence for the pre-professional and professional phases in the training of chemists. A similar diagram will be available for the training of chemical engineers. Figure 8 shows a comparison among the three professions of the percentage of effort (not time) devoted to each of the major areas of study during the first two phases of the program. Similar sets of specifications of study will be available for the specialist phase for each of the professions.

LABORATORY FACILITIES

The model program will use five types of laboratory facilities: (1) General Resources Laboratories include facilities used by all students of universities, colleges

Figure 4

Diagram of Specification for Study Sequence for Pre-Professional Program for Chemistry Teacher

Language Arts & Humanities	Lab. Exp.	Language Arts & Humanities
Social Science		Social Science
Chemistry	Pre-prof.	Chemistry
Mathematics	Estm.	Mathematics
Health Education	5-6 wks.	Health Education

Para- and Professional Education

and Advisor-Advisee Seminars

Mns	0	1	2	3	4	5	6	7	8	9

Language Arts & Humanities	Lab. Exp.	Language Arts & Humanities
Social Science		Social Science
Biology	Pre-prof.	Biology
Mathematics	Estm.	Chemistry
Health Education	5-6 wks.	Health Education

Para- and Professional Education

and Advisor-Advisee Seminars

Mns	9	10	11	12	13	14	15	16	17	18

Figure 5

Diagram of Specifications for Study Sequence for Professional Program for Chemistry

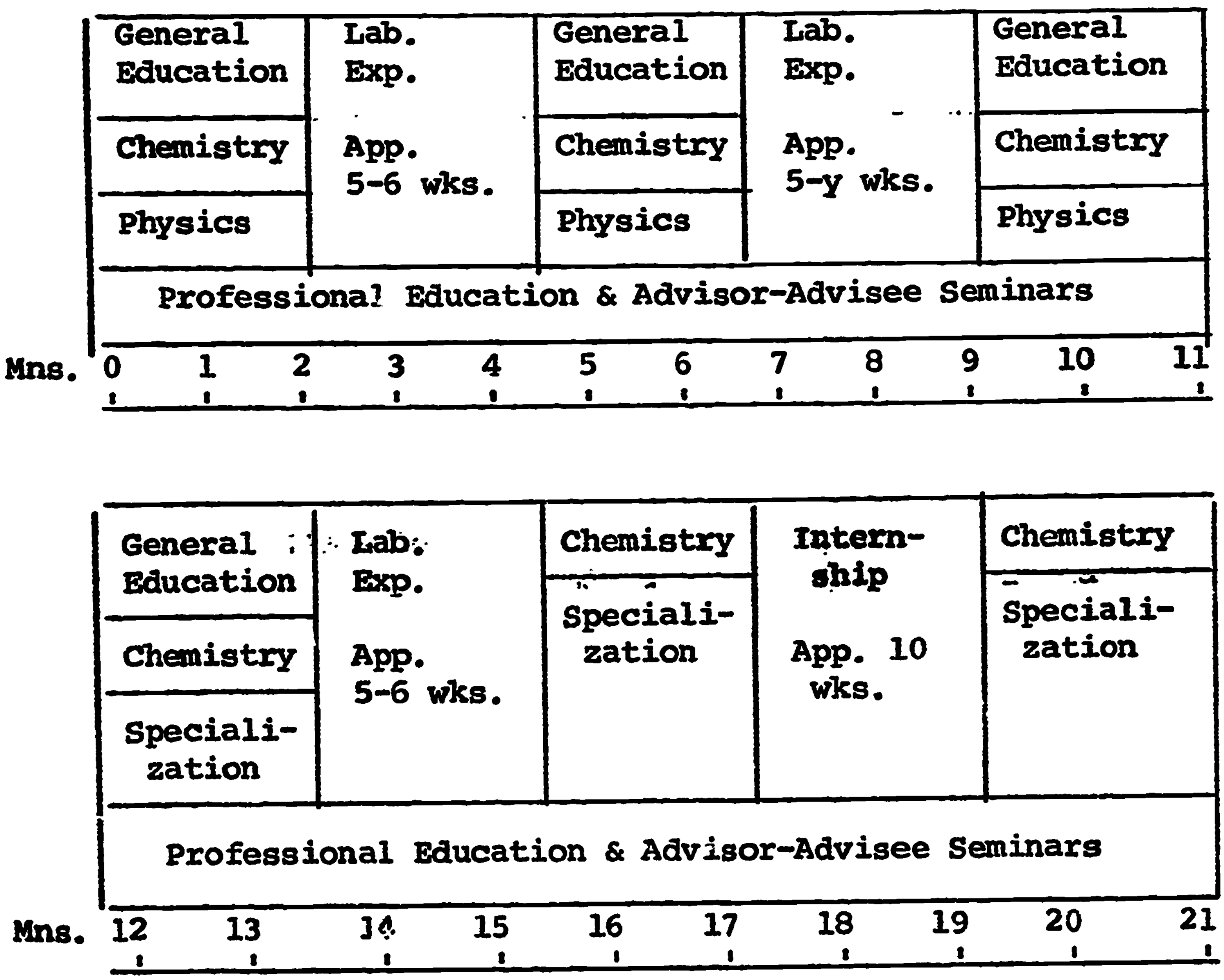

Figure 6

Diagram of Specifications for Study Sequence for Chemist Pre-Professional Program

Language Arts & Humanities	Language Arts & Humanities	Practical
Social Science	Social Science	Lab. or
Chemistry	Chemistry	Industrial
Mathematics	Mathematics	Exp.
Health Education	Health Education	App. 10 wks.
Pre-professional Seminar-I		

Mns. 0 1 2 3 4 5 6 7 8 9 10 11 12

Language Arts & Humanities	Language Arts & Humanities	Practical
Mathematics	Mathematics	Lab. or
Physics	Physics	Industrial
Chemistry	Chemistry	Exp.
Health Education	Health Education	App. 10 wks.
Pre-professional Seminar-II		

Mns. 12 13 14 15 16 17 18 19 20 21 22 23 24

Figure 7

Diagram of Specifications for Study Sequence for Chemist Professional Program

German	German	Practical Lab. or Industrial Exp. App. 10 wks.
Chemistry	Chemistry	
Special Problems	Special Problems	
Professional Seminar-III		

Mns. 0 1 2 3 4 5 6 7 8 9 10 11 12

Chemistry	Chemistry
Specialization	Specialization
Professional Seminar-IV	

Mns 12 13 14 15 16 17 18 19 20 21

Figure 8

Comparison of Percentage of Effort in Respective Areas for Secondary Chemistry Teacher, Chemist and Engineer

Area	Chem. Teacher	Chemist	Engineer
Language Arts and Humanities	10%	10%	10%
Social Science	10	10	(5)
Mathematics	13	13	15
Physics	7	7	10
German	0	7	(5)
Health Education	3	3	3
Psychology	5	0	0
Biology	5	0	0
Education	12	0	0
Chemistry	25	40	20
Engineering	0	0	32
Specialization or Electives	10	10	5
Totai	100	100	100

and schools such as central libraries and computer instruction centers; (2) Instructional Unit Central Resources Laboratories house and provide all learning materials and equipment essential for the undertaking of PMs within particular areas which are not readily or conveniently available in General Laboratories; (3) Clinics provide remedial services when required; (4) Instructional Unit Interaction Laboratories arrange for such activities as special lectures, seminars, workshops, and recitals; and (5) Instructional Unit Field Laboratories provide field facilities as needed.

The program will make allowance for more on-the-job laboratory experiences than is usually found in the traditional program. For example, during the pre-professional phase of the program for the training of high school chemistry teachers, the student will through various assignments spend a total of 10 to 12 weeks working in a school setting under the direction of an experienced teacher and college supervisor. Additional on-the-job experience is provided for in the professional phase. It is proposed that during the training of chemists and engineers three ten-week periods be spent in on-the-job experiences in industry and/or research laboratories. This experience would be provided jointly by industry and the college, with college credit being granted when the student gives evidence of having acquired the required skills. These

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on-the-job activities will provide a variety of experiences. For example, the specification of the model will require prospective teachers to work with students of differing chronological ages, races, and cultural backgrounds; prospective chemists and engineers will spend alternate periods in industry and/or basic research laboratories.

EVALUATION

Observable performance specifications will form the basis for various evaluation measures. Data storage will start with admission when an interest inventory, personality schedule, and biographical information blank will be administered. Thereafter, evaluation measures will be reviewed at the end of each block and phase of the program.

As an integral part of the on-the-job laboratory experience students will be expected to complete standard tasks and will be appraised by appropriate techniques. For certain tasks there are end products to evaluate; other tasks follow routine procedures and can be evaluated by a check list; some tasks can be checked for accuracy and other tasks require rating schedules. Learnings in the affective domain are appraised predominantly in laboratory experiences.

After all PM measures have been administered for a given block of the program, the progress of the student will be reviewed by an advisor. The advisor critiques performance in the PM block, using all data available and the student is either permitted to advance to the next block, is retained for further training, or is referred for special advisement.

Continuous long-range overall program evaluation will be conducted by outside specialists and appropriate changes made in the curriculum to reflect the recommendations of these evaluations.

RATIONALE

This paper has described an exemplary curriculum for higher education with the expectation that most would agree that the design is theoretically sound. However, there is considerable theoretical justification for the program that should be presented since much time and effort was devoted to this aspect in the original investigation.[2] The following ten principles which reflect the essential characteristics of the model have been selected as illustrative of the program designer's theoretical concerns.

1. The program should satisfy society's present and future needs.
2. The program should be systematically planned in terms of goals and objectives stated such that they may be reduced to behavioral terms.
3. Content for the program should be organized according to what is known regarding how students learn most effectively.

4. Instruction should be controlled by an achievement or a mastery variable rather than time and letter grades.
5. Time devoted to learning experiences including laboratory should be only as extensive as is needed for the student to acquire the desired behavioral characteristics.
6. Instruction should consist of those methods and procedures which are regarded as the most effective for producing the desired behavioral changes.
7. Practical applications and theoretical considerations should be introduced concurrently, with stress being given to their interrelationships.
8. Evaluation should be directed toward determining the extent to which the student has attained the characteristics reflected by the objectives.
9. Student evaluation should be systematically followed-up after the student begins his professional work to provide data for program revision.
10. Wherever quality and efficiency of learning or procedures for the development and improvement of educational programs can be enhanced through the applications of technology, effort should be made to incorporate its benefits into the system.

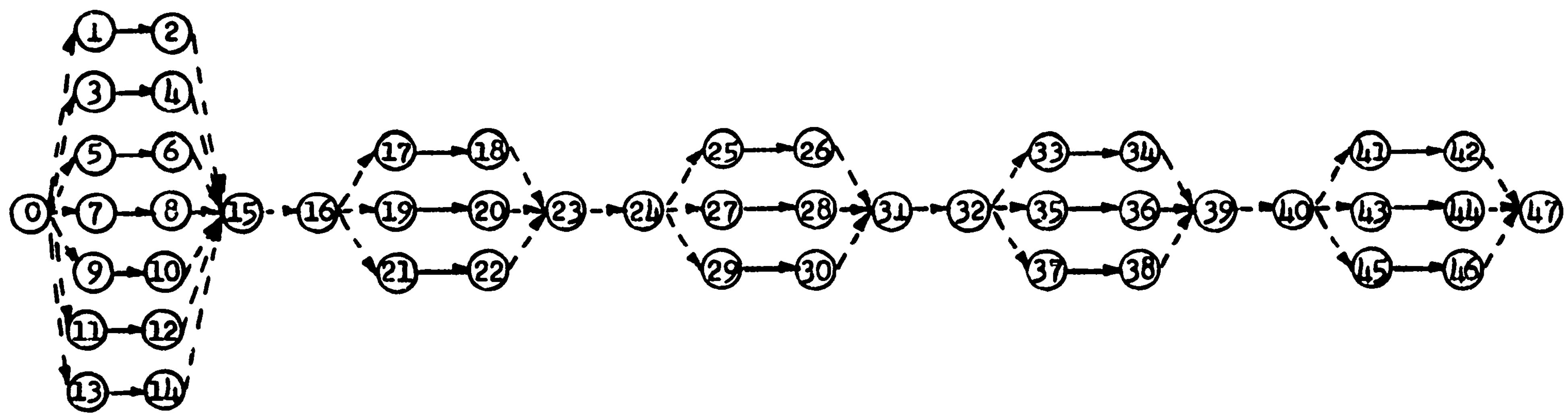
These principles when combined with others contained in the original study require the application of strategies and systems technology characteristic of research and development efforts in space, military, and industrial operations. Here again this paper can only be illustrative. Figure 9 presents a Program Evaluation and Review Technique (PERT) chart depicting the sequence of events and activities which would be required were an exemplary program for high school chemistry teachers, chemists, and chemical engineers to be developed without the benefit of previous studies.

The network is composed of events and activities. An event represents the initiation or completion of an activity and is shown in circles. For example, event number 0 represents the start of the program and is so indicated in the identification of activities. An activity consumes time and resources in proceeding from one event to another. An activity is indicated by an arrow. For example, the arrow connecting events 1 and 2 represents the activity required in the study of societal requirements.

The summary network presented proceeds from the start of the system on the left side, event 0, through the completion of specifications for the model in event 47. In the network there are a number of modal points, for example, event 31 is "complete job analysis." This must be completed prior to starting the specifications, event 32. As indicated in the network, activities proceeding from event 1 to 2, 3 to 4, 5 to 6, etc., all occur concurrently.

Figure 9

CONCEPTUAL SUMMARY NETWORK FOR DEVELOPMENT OF MODEL



Identification of Activities

0	Start program
1-2	Study of societal requirements
3-4	Accumulate knowledge of society
5-6	Study recommendations of professional societies
7-8	Study of learning processes and technology
9-10	Study of observations of jobs
11-12	Accumulation of knowledge of pedagogy
13-14	Observations of products of professional workers
17-18	Analyze job of high school chemistry teacher
19-20	Analyze job of chemist
21-22	Analyze job of chemical engineer
25-26	Write detailed job description of high school chemistry teacher
27-28	Write detailed job description of chemist
29-30	Write detailed job description of chemical engineer
33-34	State performance requirement behaviors of high school chemistry teacher
35-36	State performance requirement behaviors of chemist
37-38	State performance requirement behaviors of chemical engineer
41-42	Write specifications of instructional subsystem
43-44	Write specifications of evaluation subsystem
45-46	Write specifications of management subsystem
47	Specifications for model complete

Since one of the purposes of the network is to provide details of procedures which cannot be adequately described in narrative, the authors refer the reader to the illustrative network without further discussion.

SUMMARY

Figure 10 shows a summary of the essential characteristics of the exemplary program. The program will have as its base performance specifications which will be lists of competencies which encompass performance. They will be developed with all aspects of personal and professional development given concern.

Instruction will be both individualized and clinical. All learning activities will be directly related to performance behaviors and utilize a proficiency module as a vehicle for organizing and presenting learning activities and materials. The PMs will be designed to guide student learning through both individual study and group interaction toward acquiring particular behaviors.

It is estimated that the average student qualified for admission to the program will take approximately five to seven years to complete the whole sequence. This sequence is divided into three phases: the pre-professional, the professional and the specialist.

Evaluation starts with admission of the student and continues through each PM, block and phase of the program. All

Figure 10

Essential Characteristics of the Program

Performance Behavior Core

Individualized Instruction

Mastery Evaluation Criteria

Continuous Program Evaluation and Revision

Wide Professional Involvement

Application of Technology

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data will be placed in computer storage for availability for both short and long range evaluation of both individuals and program subsystems.

The program will allow for more widespread professional involvement in development and operation of the program. Applications of technology will be a key factor in the development and improvement of the program in sustained operation. Figure 11 presents a supplemental list of some other distinguishing characteristics of the program.

Figure 11

Other Distinguishing Characteristics of the Program

Career Sequences	Wide Professional Involvement
Proficiency Modules	A Management Organization
Continuous Seminars	Year Round Programs
Learning Laboratories	Staggered Registration
Extensive On-the-Job Experience	On-the-Job Learning Benefits

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